Attachment B.1: Training Flight Mission

There are two distinct components to the mission in Hawaii. The **training/experimental** flight component and the larger **general mapping mission**. This document will address the implementation and issues of the experimental mission component.

Description

The training/experimental component has been designed to investigate and determine the effects of sun angle, atmospheric, sea state, and water column characteristics on the ability of AURORA to discern reef environments and consequently establish the best configuration to optimize performance during the mapping mission. Since a maximum cloud cover of 10% has been established, aircraft deployment decision and location will depend primarily on cloud cover. This and other factors described elsewhere in this document will determine the aircraft's location at any given time. This coupled with the short duration of passage over any single location would require maintaining a contingent of observers everywhere around the Hawaiian islands. This would be difficult at best. Confining an experimental mission execution to a limited region will allow for coincident radiometric observations on the earth's surface with those collected at altitude from the aircraft.

Descriptions contained herein are designed to provide a baseline for executing the experimental mission. The stipulations outlined below are subject to alterations based on updated information and intelligence gathered during execution and may therefore be changed accordingly.

Kane'ohe Bay Test Area

Kane'ohe Bay has been chosen as the candidate site for the training area by adequately addressing various requirements. This region is located along the southern extent of northeast facing shore of Oahu (fig 1). It contains a variety of habitat assemblages including coaralline structures, chlorophyte beds with mixed extents of sand and pavement at multiple bottom depths ranging between 1-10m. Specific sites within the bay have been chosen based on unique, spatially homogenous habitats and the spectral characteristics associated with them. Dependent upon bottom type, 6 to 12 separate areas of sand or calcareous algae have been identified for data collection. The area currently is an active site for coral reef ecology, biology, water quality and mapping research. This knowledge base provides the background information necessary to identify specific target areas within Kane'ohe Bay. Optimizing the collective body of knowledge and expertise of the area will help to ensure an effective mission. Consequently Dr Eric Hochberg (candidate) of the University of Hawaii has provided a description of a radiometric data collection needs outlined below and elaborated on in attachment B.2.

Test Flight Description

. Aircraft operations will conduct several flights over the area collecting HSI data spectrally resolved at 10 and 5 nm bandwidths between 350 to 950 nm and at cross track spatial resolutions of from 2 and 4 m. These will be performed over a region contiguous with the mapping mission flight line area. The sequence of test mission flights will take place at 2 altitudes: 6,000ft and 12,000ft. A likely scenario will be two sets of flights at each altitude starting with the lowest altitude and the highest spectral resolution as shown in table 1 and ending with the 12,000ft altitude under operational mapping protocols. At the end of each altitude/band sequence a flight will be made over the Kane'ohe Marine Base airfield will be performed for navigational accuracy confirmation. This sequence will provide several advantages both in facilitating the execution and in providing a replete set of mixed data characteristics for post processing comparison and stability analysis. First it will allow us to examine navigational accuracy of the rectified results. Secondly, the repeating flights will provide sufficient duration to ensure that the in-situ spectral measurements will be coincident with at least one overpass at different *in-situ* sample sites. In addition the multiple altitudes, spectral and spatial resolutions will allow for subpixel analysis capabilities at subordinate resolutions. Lastly, it will provide a data set to examine extrapolation accuracy analysis to ensure consistencies both within the methodologies employed and the intrinsic heterogeneity of ground-truthing data collected over space and time.

To ensure the widest possible range of hyperspectral sensor settings over the Kaneohe Bay Test Range, a series of overflights will be conducted with varying system and aircraft parameters. The intent of these settings is to provide a range of both spatial and spectral resolutions to determine the optimal settings for various types of remote environmental measurements. The aircraft and parameter settings can be seen as follows:

Table. 1. Test Area Flight Line Parameters

Aircraft Altitude:		6000'	12000'
Sensor Settings *Spectral Resolution* **Lens Focal Length**	5nm / 12.5mm		*2 x a*
	10nm / 12.5mm	*2 x b1 + b2*†	*2 x c*
	10nm / 25mm		*2 x d1 + d2*†

† A pair of lines will be flown to cover the same area as the single 12,000 line.

The pattern of passes will be (line-direction) b1-N, b1-S, b2-N, d1-S, d1-N,d2-S,c-N, c-S, a-N,a-S. To complete this pattern will take approximately 110 minutes, assuming no bad passes. Passes will be made first in one direction along the transect and then repeated in the opposite direction.

a.

Aircraft speed is assumed to be 220 kts with a sensor frame rate of 30 Hz. This results in a square 3.7 x 3.7m pixel with 120 bands. Swath width is 12,000ft .

b1,b2.

Aircraft speed is assumed to be 200 kts with a sensor frame rate of 60 Hz. This results in a square 1.8 x 1.8m pixel with 60 bands. Two lines with approximately 20% side lap will cover 10,800ft wide area

c

.Aircraft speed is assumed to be 220 kts with a sensor frame rate of 30 Hz. This results in a square 3.7 x 3.7m pixel with 60 bands. The sensor configuration and location of this line is coincident with the mapping mission line, 24-203. If conditions and time permit, this line will be flown according to mapping mission requirements along the entire extent of the mapping line(62km) for one of the pair of passes.

d1,d2.

Aircraft speed is assumed to be 200 kts with a sensor frame rate of 60 Hz. This results in a square 1.8 x 1.8m pixel with 60 bands with a reduced atmospheric effect compared to *b*. Again 2 lines will be flown to cover the same footprint area.

Sun Angle

. The sun angle (vertical elevation angle measured between a horizontal plane and solar ray) limitations for the HSI for the Kane'ohe Bay mission will not be restricted to that of the photogrammetric requirement. This restriction will be changed to sun angles of 25°-60° during the Kane'ohe Bay flights. The lower angle will occur at approximately 7:00 while the 60° angle happens at 10:20 at an azimuth of 75° and 85° respectively. The HSI sensor has an effective instantaneous field of view 1milliradian per pixel and 1024 pixels oriented perpendicular to the direction of flight. The orientation of the flight lines over Kane'ohe Bay are approximately 145° with a look azimuth of 235°. The time of day when a Sun azimuth of 235° occurs is at 14:18 local. This allows a relaxation of the sun angle requirement while collecting HSI.

In addition, the local shoreline covers the area south and westward of the axis of flight and photo orientation. Land will effectively block sun glint from those orientations. Photographic endlap is 60%; therefore, depending on wave climate, sun elevation angles of up to 60° may be possible and should not interfere with photogrammetry collection should that be requested. Therefore, unless the plane is flying at right angles to the solar azimuth and the sun elevation is above 60°, HSI data may possibly occur throughout the day under cloud free conditions.

Each test flight over the area will take approximately 3 minutes to complete. If time permits, the mapping mission lines in the area will also be flown. There are 2 mapping lines at 62 km and 1 mapping line at 17km with a single crossing line . The 62km will take 10 min each while the 17km lines will require less than 3 minute each. Allowing 10min for turns and alignment, the 9 lines should take 1hr 45min.

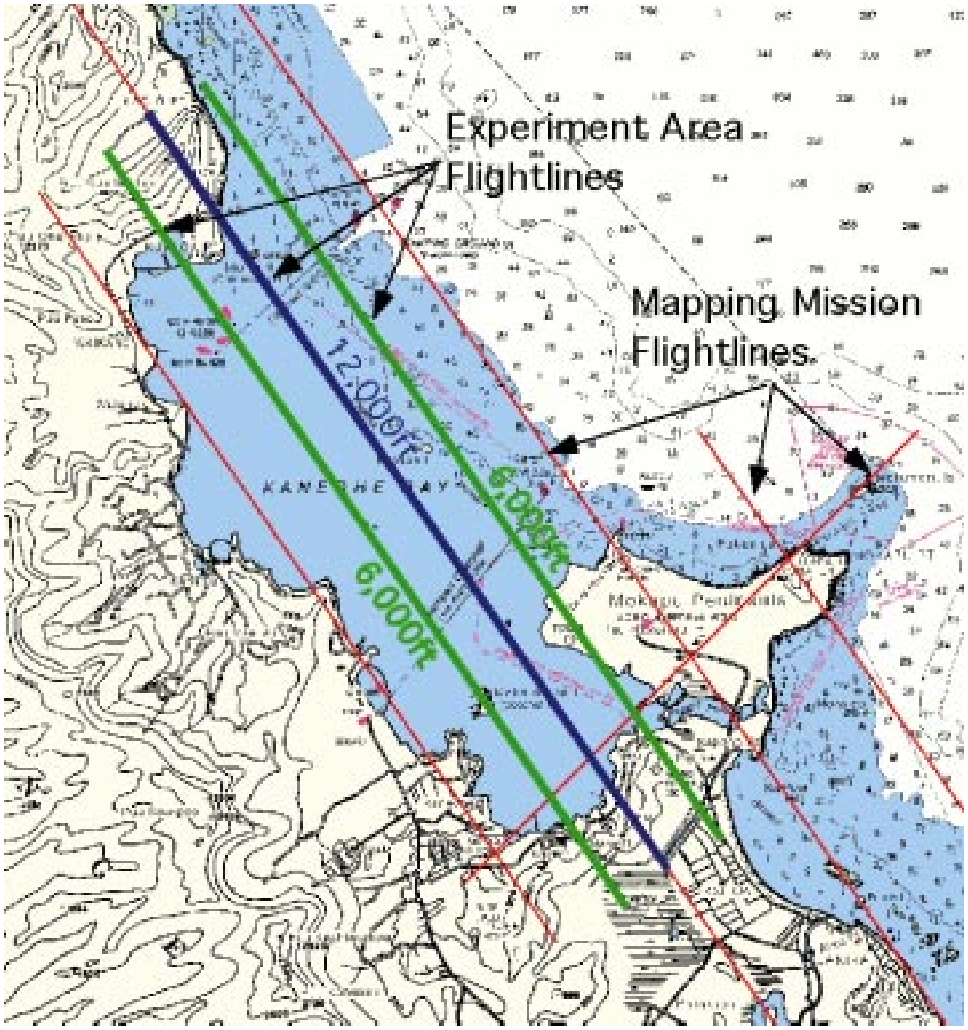

Fig 1

Ground Data Collection

Data will be evaluated to determine the need for various *in-situ* data parameters for their contribution to the hyperspectral discrimination algorithms. Since the AURORA sensor collects only upwelling irradiance from the earth's surface, any reflectance calculations will have to be based on spatial and temporal extrapolation of surface environmental conditions to the altitude of the aircraft at the time of collection. The current post processing applications for the AURORA data set are based on the calibrated irradiance data and has demonstrated robust results for some terrestrial applications. Therefore, the various measurements collected *in-situ* (see Table 2) will provide the data necessary for several post calibration adjustment techniques and allow for sensitivity assessments of the spatial and temporal heterogeneity of the measurements. In addition the in-situ information will provide the means for approximating surface reflectance measured at the aircraft. The acquisition of these data will allow for the comparison of the results from ground-truthed and non ground truthed data to occur.

The idea is to sample each of the measurable sources of radiant energies in order to solve for the unknowns (see attachment B.2) and apply that data to the image data collected by the aircraft. The variables of sources of radiant energy include the sun and its angle, atmospheric scattering, absorbtion, and transmission characteristics, scattering sources of other diffuse radiant energy and several others. The unknowns are those influences which reduce (spectrally linear) and modify (nonlinear) the reflected solar radiant flux. These include atmospheric and water column attenuation, cloud reflection and the like. Assuming that these factors don't significantly vary over small distances (10s of Km) or during short time spans (1-2hrs), an attempt will be made to collect the more important measurable parameters and calculate unknowns during the data collection at as many different locations as possible (Fig 4.). Towards this end, measurements will be made at various locations. In a vertical context data will be collected in the water column (A), at the surface (B) and at the aircraft (C). This assumes that the difference in the spectral signatures is an empirical measure of the various modifiers. These measurements will also be made at different locations horizontally to include differing bottom coverage, water depth and water conditions (if possible) along transects established by previous research (1, 2, 3, 4). A more detailed description of this component can be found in Appendix B.2.

The current list of parameters to be collected include upwelling and downwelling irradiance, at the surface (Eu+,Ed+), just below the surface (Eu-,Ed-) and at multiple spaced intervals down to depth (K) where a target reflection (albedo) value will be measured (A). To ensure consistent properties, the data will be collected over a homogenous bottom coverage of sand. This same sequence can be repeated over other homogenous or variegated bottoms later, only after the test area experimental flights have been flown. Surface irradiance will be measured using a Spectrix or similar spectroradiometer and water column values as well as bottom target data to be collected with an ASD and LICOR UW-1800. Broadband LICOR PAR spectral data will also be collected from a continuously operating station at the research facility on Coconut Island in the middle of Kane'ohe Bay. The execution will require 3 boats. One boat (boat "A") collecting bottom target reflectance, another boat (boat "B") collecting surface reflectance, and a third boat (Boat "C") acquiring water attenuation and turbidity measurements. Because any single vessel can occupy only one place at a time, measurements which take little time will be conducted. Since the plane will be flying multiple passes the area, there is a good chance that during any single pass

These data enable the temporal and spatial comparison of integrated irradiant conditions at the surface. The last set of data to be collected will be reflected radiance data off of asphalt surfaces (roads) during both the test mission and the operational coverage. These targets exhibit similar characteristics to a lambertian surface, which can be used to measure solar downwelling irradiance. If this assumption is valid the calibration information, solar irradiance can be determined in the AURORA data set at the sensor head at altitude, thus enabling the calculation of reflectance directly from the image data, atmospheric conditions notwithstanding since they cancel out.

Data Variable	Bottom Reflectance (E_u-,Ed-)	Bottom Reflectance (Eu-,Ed-) þþ	Water Surface Reflectance	Water Attenuation (K)	Position	Dry Target Reflectance	Dry Target Reflectance
Device	UH ASD	UCSB ASD	CCMA SPECTRIX	LICOR UW-1800	USCG DGPS/TRIMBLE 4000	CCMA SPECTRIX	NASA ASD
Vehicle	Boat A	Boat B ?	Boat B	Boat C	A,B,C,D	N / A	Car D
TIMING	Coincident w / overflight	Coincident w / overflight	Coincident w / overflight	± 2hrs	At Collection	Coincident w / overflight	ANYTIME
LOCATION	Kane'ohe Bay	Kane'ohe Bay	Kane'ohe Bay	Kane'ohe Bay	Kane'ohe Bay	To Be Determined	To Be Determined
Collector	E Hochberg	UNK?	R Ives	E Hochberg	J Klein	D Pirhalla	UNK?

Table 2. Ground-Truthing Resource Matrix

Attachment B.2. Experimental Area Ground-Truthing Description

Proposal to NOAA for Hawaiian Coral Reef Mapping Mission
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Objective

The NOAA Hawaiian Coral Reef Mapping Mission plan includes a hyperspectral imaging flight over Kaneohe Bay, Oahu, Hawaii. We propose to perform ground calibration, radiative transfer correction, and image classification steps that will enable further ecological interpretation of the collected imagery. Over the past five years, we have developed the theory and algorithms necessary for such image processing. This NOAA mission is an excellent opportunity to demonstrate the effectiveness and accuracy of airborne hyperspectral imaging.

<u>Ground Calibration Measurements</u>
In our algorithms, there are 3 variables for which it is necessary to make in situ calibration measurements: downwelling irradiance at the sea surface Ed(0), bottom albedo A at known locations, and bottom depth H at the same known locations. A fourth measurement of the diffuse attenuation coefficient for downwelling plane irradiance Kd is also desirable. The reasoning behind these in situ measurements is discussed in the Radiative Transfer section at the end of this proposal. In theory, all calibration measurements should be made concurrently with image acquisition. As discussed below, however, there is some temporal leeway.

<u>Measurement of $E_d(0)$</u>
Ideally, Ed(0) should be measured in the same location and at the same time as the airborne hyperspectral imagery is collected. Because the Kaneohe Bay flights will be limited in both space and time, it will be possible to directly measure Ed(0) concurrently with image acquisition. Moreover, it will be possible to directly measure Ed(0^-) and Ed(0 +), which represent downwelling plane irradiance just below and above the sea surface, respectively. Knowledge of these two quantities allows for empirical estimation of the sea surface transfer function for Ed. Measurements on upwelling irradiances Eu(0 -) and Eu(0 +) allow for similar estimation of the Eu sea surface transfer function.

We will measure $E_d(0\ )$ concurrently in space and time with image acquisition.
To accomplish this, we will have two boats, each with a spectrometer, near either end of the airplane s flight line in Kaneohe Bay. Each boat will have a driver and a spectrometer operator. Each boat will move to cover as much as possible of the flight line at the time of overflight. Using the measurements obtained from the two boats, we will estimate Ed(0 +) for the entire flight line. When time permits, possibly between

overflights, at least one boat will measure the remaining three irradiances. We will extrapolate the sea surface transfer functions to the entire flight line.

In some situations, this intensive sampling may not be logistically feasible. We suggest that it is possible to compute Ed(0 +) directly from the imagery, utilizing spectral albedo measurements of terrestrial targets taken near in time to image acquisition. Essentially, any large homogeneous feature such as a grass lawn, sandy beach, or paved road can serve as a natural calibration target . With a known albedo for a dry target within a given image, it is possible to compute $Ed(0^+)$ for that image by AT = Eu(0)/Ed(0 +), where AT is the albedo of the target and Ed(0) is the quantity measured by the remote sensor. This Ed(0 +) can then be used with estimated sea surface transfer functions in radiative transfer computations that correct for atmospheric and water column effects in the imagery. Use of several calibration targets will result in better spatial estimates of Eu(0 +) and better radiative transfer corrections.

The Kaneohe Bay flight line affords us the opportunity to test this method and compare results with directly measured values. We will identify large, homogeneous dry areas that are likely to be included in the imagery. We will then locate these objects on the ground and measure their spectral A_T on the day of the mission.

Measurements of A and H

Our radiative transfer correction algorithm removes water column effects from the remote sensing imagery, essentially leaving an image of bottom albedo (or reflectance). Measurements of A and H are necessary for calibration of the algorithm to local water column conditions. With known A and H at certain points in an image, it is possible to estimate water column optical properties directly from the image.

We will measure spectral A and H on several large, homogeneous sand areas along the flightline on the day of the mission. We will use these measurements with the collected imagery to estimate water column spectral attenuation and spectral backscatter (see Radiative Transfer section).

We use an Ocean Optics S2000 fiber optic spectrometer, operated and monitored by a Toshiba laptop computer. A 30 m fiber optic cable (400 µM inner diameter, 0.22 NA) transmits light from the collecting tip to the spectrometer. To save a spectrum, we point the collecting tip at the desired object and press a trigger button (at the end of 30 m trigger cable). Upon triggering, the spectrum is automatically saved onto the hard drive of the computer, after which the spectrometer is immediately ready to collect the next spectrum. In shallow water (0 — 3 m), spectrometer integration time ranges from 25-150 ms. Thus, it is possible to collect several spectra in a very short time frame.

To measure A for in situ objects, we collect spectra over the object and over a reference target (Spectralon). Spectral A equals the object s spectrum divided by the Spectralon spectrum. To avoid diver interference on the light field immediately surrounding the object of interest, we attach the collecting tip of the fiber optic cable near end of a 2.5 m black pole, which is extended horizontally away from the diver s body when collecting spectra. A 10 cm black stick at the end of the pole ensures consistent sampling distances between objects.

Our current spectrometer configuration limits our in-water sampling to bright daylight hours and to shallow water (depth less than 3 m). Furthermore, the shallow nature of our measurements results in significant wave focusing effects on the light at the reef surface, and up to 30% of collected spectra must be discarded. Addition of a light source and source fiber will enable us to make spectral measurements at virtually any time of day. Also, with a constant light source we will be able to prevent wave focusing from contaminating our measurements, and our signal-to-noise ratio will increase substantially.

Our methods for measuring H will depend on the depth of the water. For water less than 5 m deep, we will use a weighted measuring tape. For water depths greater than 5 m, our spectral measurements will necessitate scuba, and we will record H from a SCUBA depth gauge. Because these measurements will not be concurrent with image acquisition, we will correct the values of H for tide level using U.S. Navy tide tables.

Measurement of Kd

As noted above, Kd can be estimated directly from remote sensing imagery. We plan to measure in situ Kd as corroboration of image-estimated attenuation. We will perform image processing using both the in situ and image-estimated values, and we will compare the results.

To measure spectral Kd, we will use a LI-COR LI-1800UW spectroradiometer lowered from a boom off the side of a boat. As it is lowered through the water column, the LI-1800UW measures spectral Ed at several depths. Kd is then calculated as

$$K_d\left(\frac{z_1+z_2}{2}\right)=\frac{1}{z_2-z_1}\ln\left(\frac{E_d(z_1)}{E_d(z_2)}\right)$$

where z1 is depth at measurement 1 and z2 is depth at measurement 2. With several Ed measurements per meter, we will construct a depth profile of Kd. For comparisons with image-estimated K, we will compute a bulk water column Kd that integrates the depth profile. We will measure Kd at locations along the flight line on the day of the mission.

Radiative Transfer Corrections

We will perform radiative transfer corrections to correct for atmospheric and water column effects on the airborne hyperspectral imagery. Essentially, this involves inserting the in situ and image-estimated optical properties into radiative transfer equations and solving for unknowns such as sea surface reflectance, water depth, and bottom reflectance. Sea surface reflectance is calculated as Eu(0 +) Ed(0 +), or Eu(0 -) Ed(0 -). With our in situ measurements, we can effectively force an atmospheric correction on the imagery by computing this reflectance. We have also developed an algorithm for calculating water depth directly from hyperspectral remote sensing imagery. The algorithm utilizes our knowledge of various reef bottom albedos and the equations described in the Radiative Transfer section. The algorithm has been successful to water depths of 8 meters. Finally, with known water depth and water column optical properties, we are able to calculate bottom spectral albedo A, again using equations described later in this proposal.

Image Classifications
In theory, all objects exhibit a spectral response pattern that is a function of the structure and component materials of the object. The spectral response pattern can be so characteristic that it describes a signature for the object. This is the basis for remote sensing image classification. In our case, spectral albedo A describes the response pattern of the various reef bottom types. Once the imagery has been corrected for atmospheric and water column effects, the classifier (statistical method for identifying classes or groups in multivariate data) uses A to identify pixels in the image. Without prior knowledge of A, the classifier typically describes natural statistical groupings in the imagery. With prior knowledge of A, the classifier becomes a predictive tool for identifying specific classes within the imagery. That is, given a training set, the classifier can identify pixels by their probabilities of being one of several classes.

We have built a library of over 5,000 spectral albedos of coral reef bottom types in Kaneohe Bay. We plan to use this data set to train a classifier that can then be applied to the remote sensing imagery to be collected by NOAA in Kaneohe Bay. A smaller-scale example of this type of classification can be found in Hochberg and Atkinson (2000).

Radiative Transfer
Radiative transfer theory is essentially a radiance transfer equation (RTE) and an associated set of boundary conditions that govern the behavior of light within natural water bodies (Mobley 1994). Remote sensing of shallow oceanic waters involves interpretation of radiometric signals representing light that has interacted in some way with the water (and bottom). Thus, accurate remote sensing requires understanding of the RTE and the processes it describes.

In fact, the RTE and its associated boundary conditions are fairly complex. Their solution relies on knowledge of a water body s spatially-dependent (horizontal and vertical) inherent optical properties as well as the geometric radiance distribution. Typically, the number of unknowns exceeds the number of equations. Several theoretical solutions and empirical algorithms have been proposed for the interpretation of remote sensing signals over shallow waters (e.g. Lyzenga 1978, Mumby 1996). A common model for shallow water reflectance derives from the two-flow irradiance transfer equations (themselves derived from the full RTE). Maritorena et al. (1994) show the derivation for the equation:

$$R(0,H) = R_{\infty} + (A - R_{\infty})e^{-2KH}$$

Here, R(0,H) is diffuse reflectance at null depth over a bottom at depth H, R is diffuse reflectance over the same water with no bottom, A is the albedo of the bottom, and K is an operational diffuse attenuation coefficient. Maritorena et al. show that this model accurately describes diffuse reflectance in oceanic shallow waters (i.e. coral reef environment). Most shallow water remote sensing studies (e.g. Maritorena 1996) utilize a variation of Equation 2:

$$L_u(0,H) = L_{u,\infty} + (A - L_{u\infty})e^{-2KH}$$

where Lu(0,H) indicates water-leaving radiance over a bottom at depth H, Lu,• is water-leaving radiance over the same water type with no bottom, A is the albedo of the bottom, and K is an operational diffuse attenuation coefficient. The imaging spectrometers used in remote sensing measure radiance, so it is desirable to have a model in terms of radiance. The typical method subtracts Lu,• from both sides of Equation 3, then linearizes the result by taking the natural log of both sides.

Inspection of Equation 3 reveals some inconsistencies. First, K is a diffuse attenuation term and by definition does not apply to radiance. This can be overlooked because K is also defined as an operational attenuation, and as such we may call it beam attenuation. Second, the term A — Lu,• is a mathematical impossibility. A is dimensionless, and Lu,• has units W m -2 nm -1 sr -1 : they cannot be added. The lastinconsistency lies in the assumption that the R s in Equation 2 can be directly replaced by L s in Equation 3. Forgetting radiances for the moment, multiplied by downwelling irradiance at null depth Ed(0), Equation 2 becomes

$$E(0,H) = E_{u,\infty} + E_d(0)A^{-2KH} - E_{u,\infty}e^{-2KH}$$

where E s are irradiances corresponding to the L s in Equation 3. Equation 3 completely ignores the expansion of the A — R term.

So, it seems best to use either Equation 2 or 4, but these are in terms of irradiance, and we noted that remote sensors meaure radiance. The simplest solution to this problem is to assume that all surfaces are Lambertian (cosine) reflectors: they reflect incident light equally into all directions. Thus, L is proportional to E by the cosine of the incident light angle. Another means of obtaining Eu (upwelling irradiance) from Lu (water-leaving radiance, just below the sea surface) is to multiply Lu by a factor dependent on solar elevation (Kirk 1994).

A remote sensing image represents Lu(0,H) measured over some two-dimensional horizontal space. Often, a sensor images both a shallow reef and adjacent deep water at the same time. Because of this, it is common to take this deep water data as Lu,• . However, oceanic deep water virtually always has optical properties different from shallow reef water, which has more suspended sediment, biogenic CDOM (colored dissolved organic matter) and even phytoplankton. It is therefore questionable to use deep water in the model as Lu,• .

Here it is useful to return to Equation 2 and the reason that R is included in the first place. Maritorena et al (1994) note that bbd/(Kd + •) equals reflectance at null depth in an infinitely deep ocean. bbd is the diffuse backscatter coefficient for downwelling plane irradiance, Kd is the diffuse attenuation coefficient for downwelling plane irradiance and • is the diffuse attenuation coefficient for upwelling plane irradiance. To simplify their equations, they replace Kd + • with an operational value 2K, and then they replace bbd/2K with R . So, R does not really represent deep water; rather, it represents water of the same K and bbd with an infinitely deep bottom.

The coral reef image processing methods we employ are based on a variation of Equation 2 that partitions R into bbd and K:

$$R(0,H) = \frac{b_{bd}}{2K} + \left(A - \frac{b_{bd}}{2K}\right)e^{-2KH} \text{ R H b}$$

Because sea surface reflectance can also be expressed by

$$R(0,H) = \frac{E_U(0,H)}{E_d(0)}$$

the left-hand side of Equation 5 can be computed simply from the remote sensing imagery and concurrent measurements of Ed(0). Assuming that water in a given area over a reef is constant with respect to optical properties, further knowledge of A with varying H (co-located to known image pixels) allows for non-linear least-squares estimation of bbd and K. With known bbd and K, other algorithms involving measured values of A can be used to estimate H at every image pixel. Finally, with estimates for all the unknowns, we can calculate the bottom albedo A, and based on spectral A, we can classify image pixels into benthic community type.

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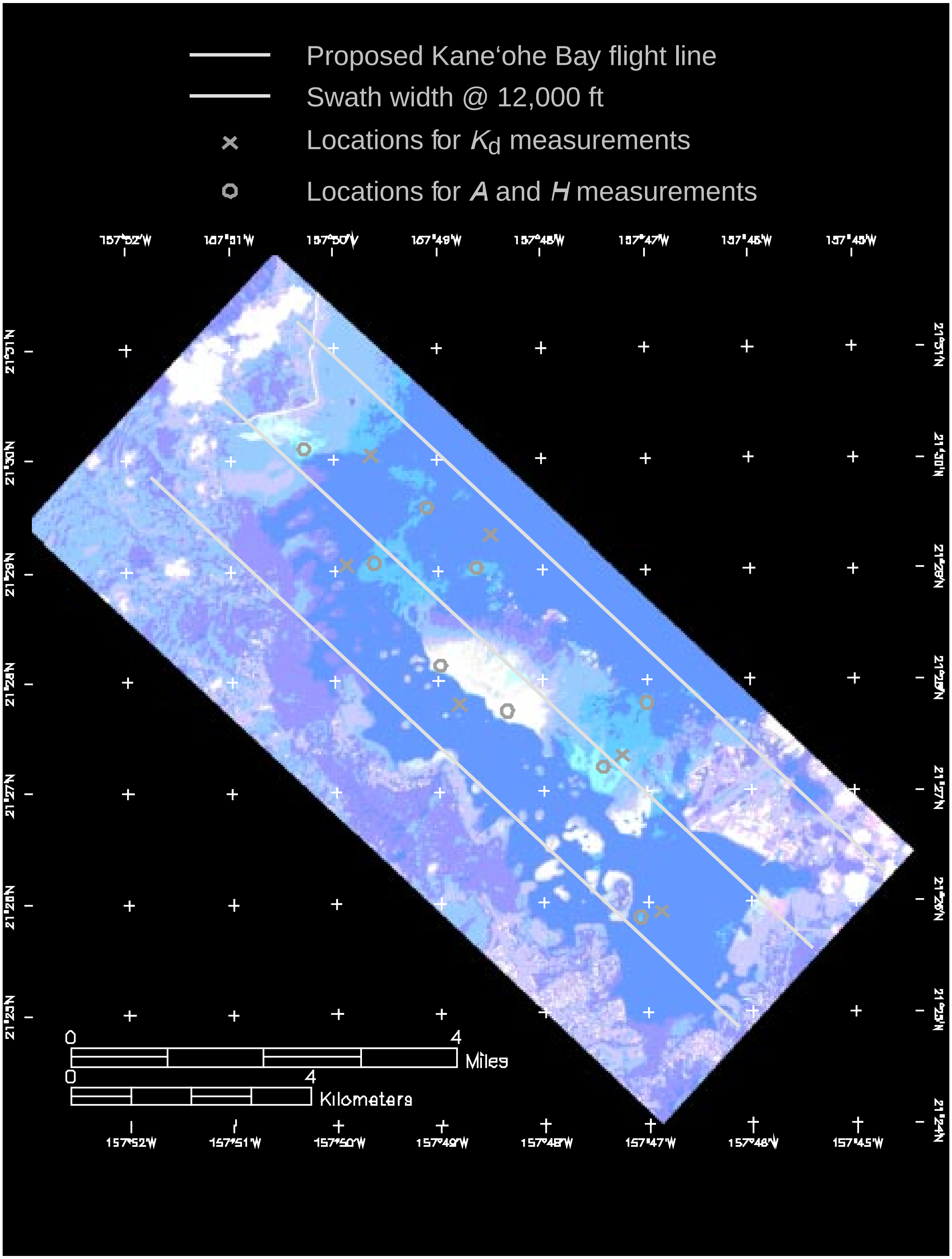
Proposed Kane‘ohe Bay flight line
Swath width @ 12,000 ft
Locations for K_d measurements
Locations for A and H measurements
157°52'W
157°51'W
157°50'W
157°49'W
157°48'W
157°47'W
157°46'W
157°45'W
21°31'N
21°30'N
21°29'N
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Miles
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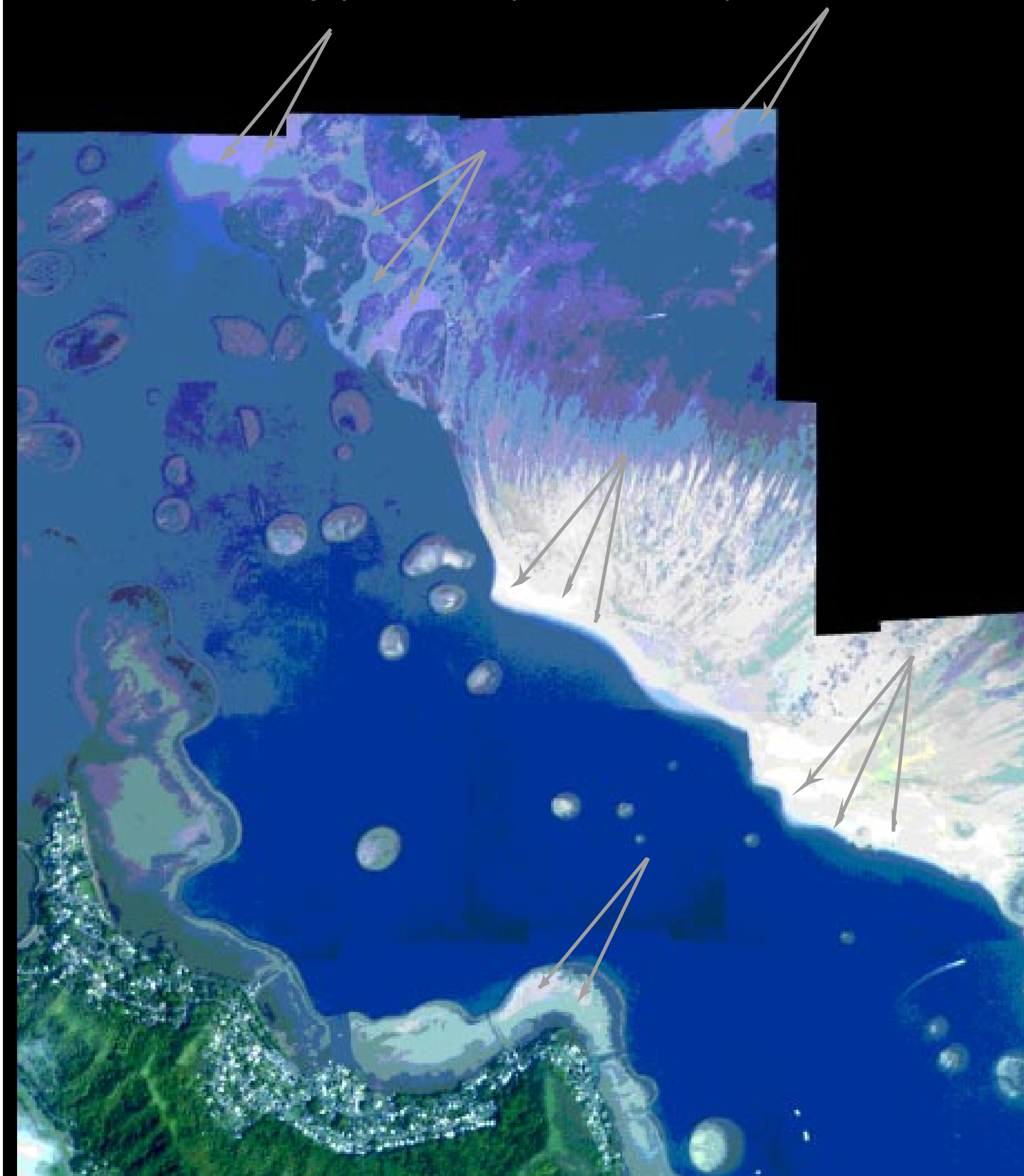

Examples of large sand areas in central Kane‘ohe Bay for use in calibrating remote sensing imagery. These sand patches have similar albedos but different depths. These types of sand patches exist throughout Kane‘ohe Bay, providing the opportunity to calibrate imagery under a variety of water column optical conditions.